21

ON A CONDITIONAL ASPECT OF THE J-PHENOMENON IN X-RAYS

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While comparing experimentally the ionizations produced by a heterogeneous primary beam of X-rays and its scattered beam in a direction at right angles to the former for different incident wavelengths, Barkla and Khastgir (1927) observed that the graph drawn with the unintercepted ratio of ionizations $(S/P)_{90°}$ against the mass-absorption coefficient $(\bar{\mu}/\rho)_{Al}$ of the primary beam transmitted through the scatterer, was a horizontal straight line parallel to $(\mu/\rho)_A$ -axis with a bending down at its harder extremity. This feature was theoretically explained by the writer in a previous paper (Pal 1965, p 119). It was also pointed out in that paper that this was not a general feature of the graph, since it depended on certain experimental conditions.

The author repeated the experiments employing unfiltered radiations with thin and thick scatterers of the same material and with apertures of different sizes for the primary beam. The object of the present communication is to report the results of those experiments and to explain them. Experiments were performed with (i) paraffin wax of thicknesses 3.2 mm. and 18.5 mm. (ii) filter paper of 10, 20 and 50 sheets and (iii) aluminium of thicknesses 0.38 mm. and 0.87 mm. as scatterers and with apertures of different sizes (having diameters ranging from 0.2 mm. to 2.05 mm.) for the primary beam. The results can be stated as follows:

(a) For thin scatterers and narrow apertures, the graph showing $(S/P)_{90°}$ against the mass-absorption coefficient of the primary beam was found to be horizontal in the proper region (as described above) but with a definite downward slope in the softer region.

(b) For thick scatterers and larger apertures, the same graph was a curve descending steadily towards longer wavelengths.

The results are illustrated by some typical graphs in Figs 1 and 2, where ratio $(S/P)_{90°}$ is plotted against the exciting peak voltage instead of against $(\bar{\mu}/\rho)_{Al}$. It may be noted that all the graphs are reduced to the same scale of reference by taking the maximum value of the ratio $(S/P)_{90°}$ for each as unity. From these graphs it appears that a smaller scattering thickness (see Fig. 2) or a narrower primary aperture (see Fig. 1) favours a greater length of the horizontal part of the graph*.

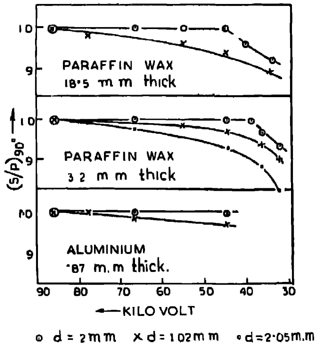

Fig. 1.

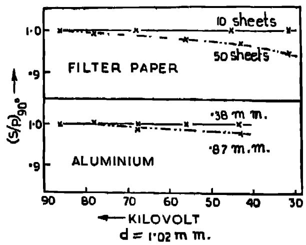

Fig. 2.

To explain the above experimental results, we have to refer to the following equation deduced in the previous paper mentioned before :

$$(S'/P')_{90^\circ} = K'\left[1-3C_{90^\circ}\left\{\frac{1}{2}Bx\lambda^3\left(r_x+\frac{\delta\lambda_{90^\circ}}{\lambda}\right)+\left(\frac{\delta\lambda_{90^\circ}}{\lambda}-r_x\right)\right\}+(A-A')x\right]$$

where $(S'/P')_{90^\circ}$ denotes the ratio of ionizations when the scattered and the primary beams are each intercepted by a thickness x of the absorbing material and the other notations are as given in the author's previous paper (Pal, 1965). We shall also take into account the following facts :

(i) Even though the beams compared are unintercepted in the ordinary sense, they have to pass through a small thickness (.01 cm) of aluminium foil covering the window of the ionization chambers receiving the two beams compared.

*Graphs of the same nature were obtained also by other workers in the same laboratory.

(ii) The absorbing thicknesses inside the scatterer, for the two beams compared being equal on account of its special setting with respect to the incident beam (method of Barkla and Ayres, 1911), the effect of the thickeness of the scattering when considered, may be regarded as equivalent to a small addition to the absorbing thickness x of the aluminium foil of the ionization chambers in the above equation.

Since $r_x \approx \frac{\delta\lambda_{90^\circ}}{\lambda}$, we can rearrange the equation as

$$(S'/P')_{90^\circ} \approx K'[1-\{3B(C_{90^\circ}\lambda^2)\delta\lambda_{90^\circ}-(A-A')\}x]$$

where x is the equivalent thickness of aluminium intercepting the two beams compared. It is to be noted that of the three variables (i) $C_{90^\circ}\ \lambda^2$, (ii) $(A-A')$ and (iii) x, the first increases as the wavelength λ is increased upto a certain maximum value (Backhurst 1934), the second depends on the size of the primary aperture, increasing as the size is diminished (Bachem 1923), the size of the aperture for the scattered beam remaining constant and the third increases as the scattering thickness is increased The quantity within the curled bracket is usually positive and when this is multiplied by x, the product represents a general lowering of the graph in question below the horizontal line drawn through the maximum value of $(S'/P')_{90^\circ}$. The extent of lowering in any particular case will, however, be determined by the relative magnitudes of the three variables referred to. Thus for very small primary apertures the quantity within the curled bracket may turn out to be vanishingly small, particularly in the harder region of the rays and if, in addition, x is small too, the lowering of the graph may be trivial, thus accounting for the horizontal course of the same obtained experimentally. With a larger value of x, of course, the horizontality will cease earlier. If on the contrary, the aperture is large and so also x, the lowering becomes appreciable even for harder rays. In the case of moderately long wavelengths, $C_{90^\circ}\ \lambda^2$ is much greater than $(A-A')$, even though the apertures for the primary rays are very narrow, so that the corresponding descent of the graph is very marked despite the smallness of x (Fig. 1).

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